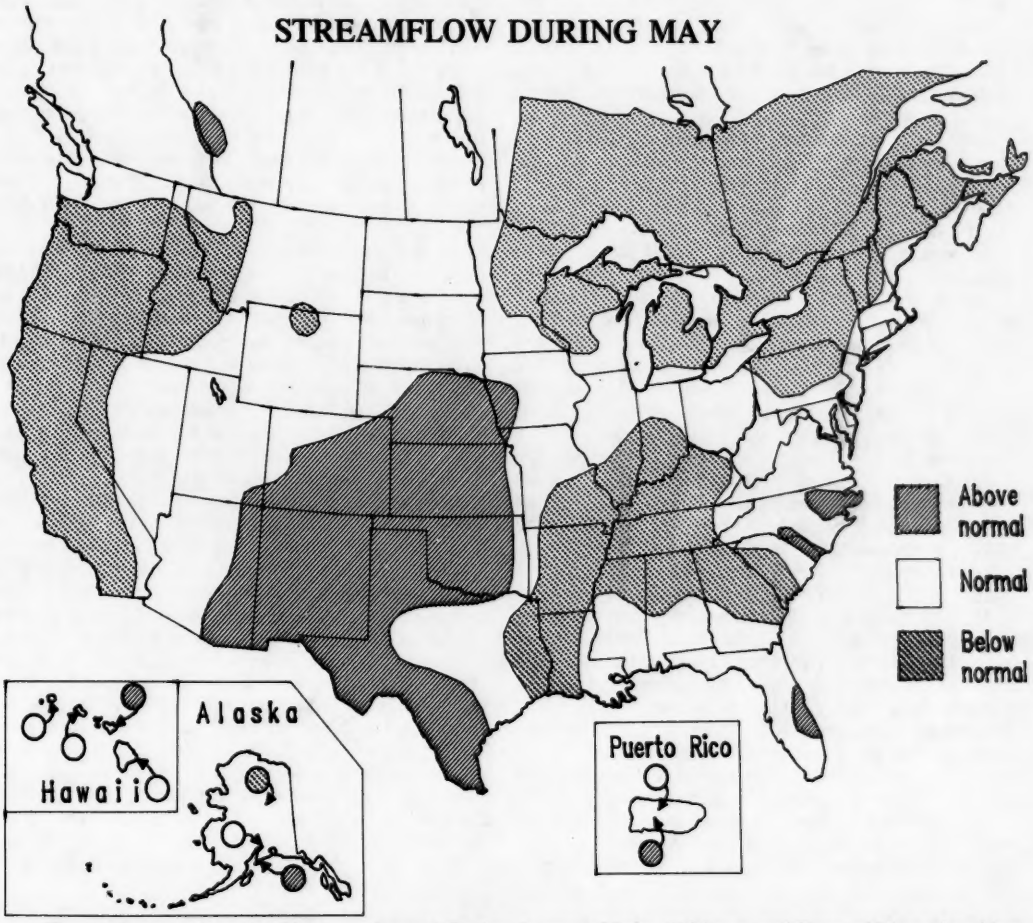
National Water Conditions

UNITED STATES
Department of the Interior
Geological Survey

CANADA
Department of the Environment
Water Resources Branch

MAY 1987

STREAMFLOW DURING MAY



Heavy rains near the end of May caused record flooding in parts of Iowa, Oklahoma, and Texas which continued into June in some areas. Three people drowned during the floods, two in Oklahoma and one in Texas. No damage estimates were available. The worst flooding in Iowa was in the Nishnabotna River basin in the southwestern part of the State where about 1,100 people were evacuated from Red Oak. The main east-west line of the Burlington Railroad (also used by Amtrak) was closed by flooding near Emerson, and the Governor of Iowa declared Mills, Montgomery, Fremont, and Page Counties disaster areas. In Oklahoma, 10 to 13 inches of rain fell May 26–28, causing severe flooding in the central and western parts of the State. Peaks of record were exceeded at nine gaging stations and the 100-year flood was exceeded at four of those stations. Several bridges were washed out and State highways were closed by flood waters. The floods in Texas began after rains of 5 to 8 inches in 24 hours fell in some areas at monthend and continued into June. A pipeline ruptured during the flooding, spilling an unknown volume of crude oil into the Red River.

In contrast, streamflow was in the normal to above-normal range at only about 58 percent of the 191 reporting index stations in southern Canada, the United States, and Puerto Rico, after generally decreasing in most of southern Canada and the United States. This is about the same percentage of stations with flow in the normal to above-normal range as in May 1986 but the combined flow of the 190 sites reporting data for both May and 1986 and May 1987 was lower in May 1987; 2,372,340 cubic feet per second (cfs) for May 1987 versus 2,819,060 cfs for May 1986. About 76 percent of stations had flow in the normal to above-normal range last month.

The combined flow of the 3 largest rivers in the lower 48 States—Mississippi, St. Lawrence, and Columbia—averaged a below-normal 1,255,600 cfs during May, 17.2 percent below median and 10.1 percent below last month's flow.

SURFACE-WATER CONDITIONS DURING MAY 1987

On April 5, 10 people were killed when flood waters caused the collapse of a New York State Thruway bridge over Schoharie Creek. As much as 10 inches of rain fell in some areas during the first week of the month. Peak discharge of Schoharie Creek at Burtonsville (drainage area 883 square miles), several miles upstream from the collapsed bridge, was 64,900 cubic feet per second (cfs) on April 5, about 11,600 cfs less than the October 1955 peak of record. Schoharie Creek at Prattsville (drainage area 236 square miles) peaked at 56,000 cfs on April 4, equaling the 100-year flood and exceeding the October 1955 flood by 800 cfs.

Location of and data for selected sites in New Hampshire and Massachusetts where April floods occurred (but were not reported on in last month's issue) are given on page 4. Peak discharges at six of these sites equaled or exceeded the 100-year flood.

Heavy rains near the end of May caused record flooding in parts of Iowa, Oklahoma, and Texas (see text on page 4 and maps and table on page 5), which continued into June in some areas. Three people drowned during the floods, two in Oklahoma and one in Texas. No damage estimates were available.

In contrast, streamflow was approaching record lows in Montana after April's high temperatures depleted a below-normal snowpack. Dry conditions continued in Idaho, but reservoir releases and ground-water base flow kept streams above record lows. The level of Oregon's Crater Lake declined 0.10 foot over the last winter, only the third time during the last 26 years (the other two times were 1973 and 1977) that a winter decline has occurred. The gage at the lake is usually snowed in until late June or early July, and the May 22 visit to the gage, at which time the decline was measured, is the earliest ever made. The Fairbanks, Alaska, National Weather Service office reported that March through May precipitation in the interior of the State was the lowest since records began in 1904. Alaska's Hubbard Glacier, which closed off Russell Fiord May 29–October 8, 1986, "had advanced to cover all but one outlying rock of Osier Island," which is at the mouth of the fiord.

May streamflow generally increased in only 11 States and Provinces: seasonally in Alaska, British Columbia, Alberta, Idaho, Montana, Wyoming, Nevada, Utah, Colorado, and Oklahoma; contraseasonally in Mississippi. Streamflow generally changed variably in Hawaii, Washington, California, New Mexico, Texas, Louisiana, and Puerto Rico. Flow generally decreased in the rest of southern Canada and the United States: variably in Nebraska and New Brunswick; contraseasonally in Ontario and Quebec; seasonally in all other areas.

Streamflow was in the normal to above-normal range at about 58 percent of the 191 reporting index stations in southern Canada, the United States, and Puerto Rico, compared with the 76 percent in those ranges for last month. This is about the same percentage of stations with flow in the normal to above-normal range as in May 1986, and the lowest since that time. New May extremes occurred at 12 index stations (see table on page 6): 2 maximums and 10 minimums. All of the minimums occurred at stations in or adjacent to the Great Lakes–St. Lawrence River basin, but not tributary to any of the lakes. Five of these sites are in Canada and five are in the United States. Hydrographs of streamflow at eight index stations, including two of those at which new May extremes occurred, are on page 18. These hydrographs illustrate a wide variety of flow conditions over the 26 months shown, ranging from 13 of 26 months in the below-normal range for the Altamaha River at Doctortown, Georgia, to 26 months in the above-normal range for the Animas River at Durango, Colorado. Flow at the latter site has been in the above-normal range for 35 consecutive months, currently the longest period of above-normal flow reported. Flow of the Mississippi River near Anoka, Minnesota, was in the above-normal range from May 1985 to March 1987, but decreased into the below-normal range in April and remained there during May.

Mean May elevations for the Great Lakes (provisional data from National Ocean Service) were lower than those for last month and May 1986, except for the level of Lake Superior, where this month's mean was the same as last month's. Levels of all four lakes remained above median. Stage hydrographs for Lakes Superior, Huron, Erie, and Ontario are on page 7.

The level of Utah's Great Salt Lake fell 0.10 foot during May, reaching 4,211.60 feet above National Geodetic Vertical Datum of 1929 on May 31. This year's decline is the earliest in recent years, but monthend lake level (hydrograph on page 7) is the second highest ever recorded for May.

May precipitation (provisional National Weather Service data) was generally an inch or more below average in the area from Kentucky northward to the Great Lakes and from the Appalachian Mountains to the Atlantic Ocean. Precipitation was generally an inch or more above average in the area from central Texas to southern Iowa. Total precipitation exceeded 6 inches at 15 cities during the month, 10 of them in Texas, Oklahoma, Kansas, and Nebraska. Those cities with more than 6 inches of precipitation which also had record-high totals for May (amounts in inches) are: San Antonio (12.85) and San Angelo (11.24), Texas; San Juan (12.16), Puerto Rico; Scotts Bluff (7.25), Nebraska. Record-low precipitation for May fell at: Los Angeles (0.00, equaling 1986) and Sacramento (0.00), California; Cape Hatteras (0.37) and Wilmington (0.93), North Carolina; Springfield (0.53), Illinois; Grand Rapids (0.94), Michigan; Columbia (2.78), Missouri. Total Precipitation and

(Continued on page 6.)

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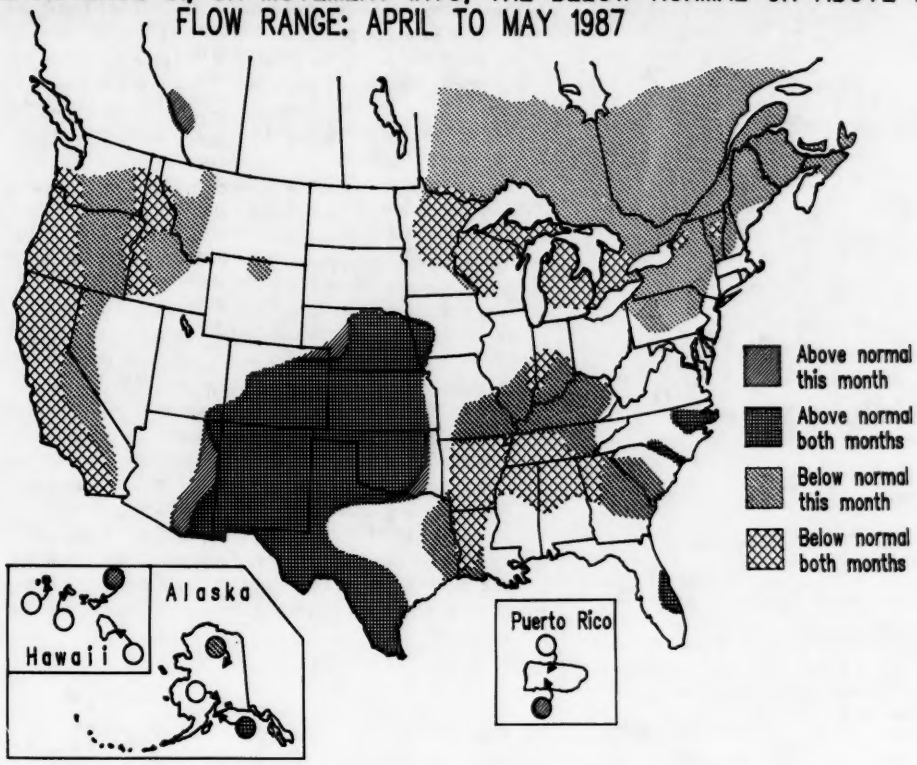
PERSISTENCE IN, OR MOVEMENT INTO, THE BELOW-NORMAL OR ABOVE-NORMAL FLOW RANGE: APRIL TO MAY 1987



SUMMARY OF MAY 1987 STREAMFLOW

[Flow ranges]

Area	Below normal range		Normal range		Above normal range		Number of stations	
	No.	Percent	No.	Percent	No.	Percent	Reporting data	Missing data
Conterminous United States.	66	40.5	76	46.6	21	12.9	163	0
Alaska, Hawaii, and Puerto Rico.	2	20.0	5	50.0	3	30.0	10	0
United States and Puerto Rico.	68	39.3	81	46.8	24	13.9	173	0
Southern Canada.....	13	72.2	4	22.2	1	5.6	18	0
Conterminous United States and southern Canada.	79	43.6	80	44.2	22	12.2	181	0
All sites.....	81	42.4	85	44.5	25	13.1	191	0

[Comparison of total monthly means with total monthly medians and last month's total monthly means]

Total of May means (All sites).....	2,374,810	CFS
Total of May medians (All sites).....	3,132,030	CFS
Total of last month's means (All sites).....	*3,145,500	CFS
Total of May means compared to total of medians.....	−24.2	Percent
Total of May means compared to total of last month's means.....	−24.5	Percent

*Revised.

LOCATION OF SITES FOR WHICH FLOOD DATA ARE GIVEN

NEW HAMPSHIRE AND MASSACHUSETTS

The worst flooding in Iowa was in the Nishnabotna River basin in the southwestern part of the State. The West Nishnabotna River at Randolph peaked at 39,000 cfs on May 26, equaling the 100-year flood and exceeding the peak of record by 4,000 cfs. About 1,100 people were evacuated from Red Oak, Iowa, where Indian Creek, an ungaged tributary to the Nishnabotna River at Red Oak, contributed most of the 11,000 cfs peak recorded at that site on May 26. Several other towns were evacuated, the main east-west line of the Burlington Railroad (also used by Amtrak) was closed by flooding near Emerson, and the Governor of Iowa declared Mills, Montgomery, Fremont, and Page Counties disaster areas.

In Oklahoma, 10 to 13 inches of rain fell May 26–28, causing severe flooding in the central and western parts of the State. Peaks of record were exceeded at nine gaging stations and the 100-year flood was exceeded at four of those stations. For example, Washita River near Dickson peaked at 105,000 cfs on May 29, 1.8 times the 100-year flood and 7,000 cfs higher than the previous maximum discharge. Several bridges were washed out and State highways were closed by flood waters.

The floods in Texas began after rains of 5 to 8 inches in 24 hours fell in some areas at monthend and continued into June. The Red River at Gainesville peaked at 262,000 cfs on May 31, 1.4 times the 100-year flood and 94,000 cfs higher than the previous flood of record. A pipeline ruptured during the flooding, spilling an unknown volume of crude oil into the Red River.

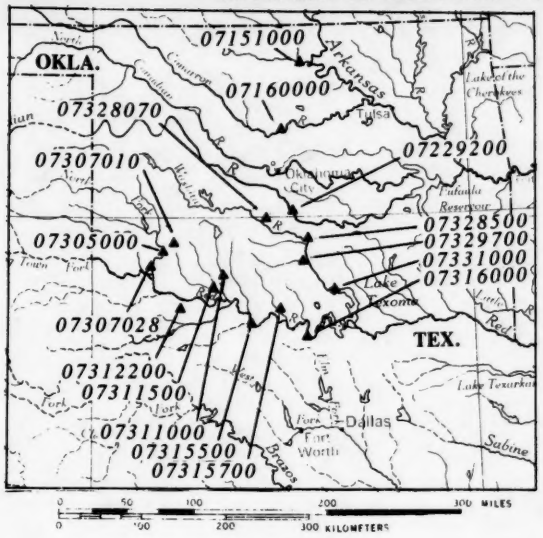
Provisional data; subject to revision

FLOOD DATA FOR SELECTED SITES IN NEW HAMPSHIRE AND MASSACHUSETTS, APRIL 1987

WRD station number	Stream and place of determination	Drainage area (square miles)	Period of known floods	Maximum flood previously known			Maximum during present flood				
				Date	Stage (feet)	Discharge (cfs)	Date	Stage (feet)	Discharge		Recurrence interval (years)
									Cfs	Cfs per square mile	
	NEW HAMPSHIRE										
	PISCATAQUA RIVER BASIN										
01073500	Lamprey River near Newmarket	183	1934–	Mar. 20, 1936	14.88	5,490	Apr. 7	15.14	7,500	41	[a]1.2
	MERRIMACK RIVER BASIN										
01085000	Contoocook River near Henniker	368	1768–	Sept. 21, 1938	21.3	22,200	6	16.0	16,000	43	[a]1.3
	MASSACHUSETTS										
	MERRIMACK RIVER BASIN										
01094400	North Nashua River at Fitchburg	63.4	1972–	Apr. 5 1984	7.02	2,740	Apr. 5	7.78	3,400	54	100
01096000	Squannacook River near West Groton	63.7	1949–	Oct. 16, 1955	8.04	4,010	6	8.16	4,220	66	55
01099500	Concord River below River Meadow Brook at Lowell.	307	1936–	Jan. 28, 1979	9.60	5,410	10	9.60	5,410	18	50
	PARKER RIVER BASIN										
01101000	Parker River at Byfield	21.3	1945–	Mar. 19, 1968	5.61	489	7	7.35	790	37	[a]1.3
	IPSWICH RIVER BASIN										
01101500	Ipswich River at South Middleton	44.5	1938–	Jan. 26, 1979	7.12	839	7	7.51	1,000	22	60
01102000	Ipswich River near Ipswich	125	1886–	Mar. 20, 1968 21, 1968	8.41	2,680	8	9.43	3,550	27	[a]1.1
	CONNECTICUT RIVER BASIN										
01169000	North River at Shattuckville	89.0	1939–	Oct. 15, 1955	10.37	13,200	5	11.19	15,300	172	60
01170000	Deerfield River near West Deerfield	557	1940–	Dec. 31, 1948	15.3	48,500	5	17.71	61,700	111	[a]1.04

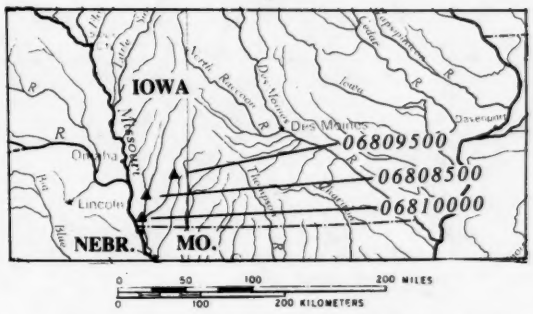
[a]Approximate ratio of discharge to that of 100-year flood.

LOCATION OF SITES FOR WHICH FLOOD DATA ARE GIVEN



← OKLAHOMA AND TEXAS

IOWA ↓



Provisional data; subject to revision

FLOOD DATA FOR SELECTED SITES IN IOWA, OKLAHOMA, AND TEXAS, MAY 1987

WRD station number	Stream and place of determination	Drainage area (square miles)	Period of known floods	Maximum flood previously known			Maximum during present flood				
				Date	Stage (feet)	Discharge (cfs)	Date	Stage (feet)	Discharge		Recurrence interval (years)
									Cfs	Cfs per square mile	
	IOWA										
	NISHNABOTNA RIVER BASIN										
06808500	West Nishnabotna River at Randolph	1,326	1948–	June 21, 1967	22.60	35,500	May 26	23.70	39,000	29	100
				Mar. 5, 1949	24.8	[a]					
06809500	East Nishnabotna River at Red Oak	894	1918–25, 1936–	Sept. 13, 1972	27.43	38,000	26	17.10	11,000	12	4
				June 13, 1947	28.23						
06810000	Nishnabotna River above Hamburg	2,806	1922–23, 1928–	June 24, 1947	26.03	55,500	27	28.05	32,000	11	20
				Mar. 7, 1979	27.46	[a]					
	OKLAHOMA										
	ARKANSAS RIVER BASIN										
07151000	Salt Fork Arkansas River at Tonkawa	[b]4,520	1935–	Oct. 11, 1973	28.98	97,300	May 27	25.26	50,000	11	40
07160000	Cimarron River near Guthrie	[b]11,966	1937–76, 1983–	May 17, 1957	18.58	158,000	28	14.75	60,000	3.9	60
07229200	Canadian River at Purcell	[b]21,138	1961–83, 1986–	May 19, 1982	14.50	50,500	28	14.75	82,000	3.9	[c]
	RED RIVER BASIN										
07305000	North Fork Red River near Headrick	[b]3,845	1905–08, 1937–	May 28, 1977	17.26	35,000	29	17.29	56,000	15	[d]1.3
				[c]	21.1	[c]					
07307010	Otter Creek near Snyder	217	1984–	Oct. 3, 1986	13.67	3,650	28	14.50	11,000	51	[c]
07307028	North Fork Red River near Tipton	[b]4,292	1983–	Oct. 3 1986	16.01	32,000	30	18.43	55,000	13	[c]
07311000	East Cache Creek near Walters	675	1938–63, 1969–	Oct. 21, 1983	30.66	50,900	29	29.72	29,800	44	50
07311500	Deep Red Run near Randlett	617	1949–	Oct. 20, 1983	28.89	72,300	29	29.58	51,000	83	50
07315500	Red River near Terral	[b]22,787	1938–	Oct. 22, 1983	33.60	210,000	30	32.65	225,000	9.9	1.2
07315700	Mud Creek near Courtney	572	1960–	May 1, 1974	31.37	33,400	28	29.50	21,000	37	20
07328070	Winter Creek near Alex	33	1964–	May 27, 1978	17.35	6,080	29	20.09	10,500	318	30
07328500	Washita River near Pauls Valley	5,330	1937–	May 18, 1957	27.34	35,800	29	28.69	45,000	8.4	[d]1.8
07329700	Wildhorse Creek near Hoover	604	1969–	May 20, 1977	24.70	18,700	28	25.75	35,000	58	[d]1.04
07331000	Washita River near Dickson	7,202	1928–	May 19, 1957	42.30	98,000	29	45.24	105,000	15	[d]1.8
				Oct. 31, 1941	44.37						
	TEXAS										
	RED RIVER BASIN										
07312200	Beaver Creek near Electra	652	1960–	Mar. 17, 1961	33.57	11,700	May 29	34.97	11,500	18	40
				Oct. 2, 1941	36.0	[c]					
07316000	Red River near Gainesville	[b]24,846	1936–	June 9, 1941	24.15	168,000	31	40.30	262,000	11	[d]1.4
				Oct. 24, 1983	37.14	151,000					

[a]Backwater from ice.
[b]Contributing drainage area.
[c]Not determined.
[d]Approximate ratio of discharge to that of 100-year flood.

NEW EXTREMES DURING MAY 1987 AT STREAMFLOW INDEX STATIONS

Station number	Stream and place of determination	Drainage area (square miles)	Years of record	Previous May extremes (period of record)		May 1987			
				Monthly mean in cfs (year)	Daily mean in cfs (year)	Monthly mean in cfs	Percent of median	Daily mean in cfs	Day
				HIGHS					
06810000	Nishnabotna River above Hamburg, Iowa.	2,806	59	6,061 (1973)	22,900 (1951)	6,150	447	31,100	27
08276500	Rio Grande below Taos Junction Bridge, near Taos, N. Mex.	9,730	61	5,993 (1941)	9,630 (1941)	6,020	679	8,100	20
				LOWS					
01014000	St. John River below Fish River, at Fort Kent, Maine	5,665	60	14,230 (1980)	6,020 (1959)	6,754	20	4,150	25
01318500	Hudson River at Hadley, N.Y.	1,664	65	1,686 (1941)	838 (1965)	1,460	29	900	23
01357500	Mohawk River at Cohoes, N.Y.	3,456	69	2,090 (1985)	8.0 (1959)	1,790	27	523	22
05362000	Jump River at Sheldon, Wis.	576	71	159 (1977)	58.0 (1955)	121	18	66	*
05365500	Chippewa River at Chippewa Falls, Wis.	5,650	98	1,980 (1931)	263 (1976)	1,484	24	175	17
01BE001	Upsalquitch River at Upsalquitch, New Brunswick, Canada	877	57	1,963 (1968)	876 (1968)	1,126	19	646	31
02QB001	Matane River near Matane, Quebec, Canada	636	64	2,580 (1951)	990 (1947)	1,450	25	. . .	. .
02OF002	St. Francois River at Hemmings Falls, Quebec, Canada	3,710	60	3,210 (1941)	1,480 (1977)	3,160	35	. . .	. .
02NG001	St. Maurice River at Grand Mere, Quebec, Canada	16,200	86	27,100 (1980)	10,800 (1941)	10,500	15	. . .	. .
04LJ001	Missinaibi River at Mattice, Ontario, Canada	3,452	66	4,838 (1923)	1,070 (1926)	2,652	17	1,518	31

* Occurred more than once.

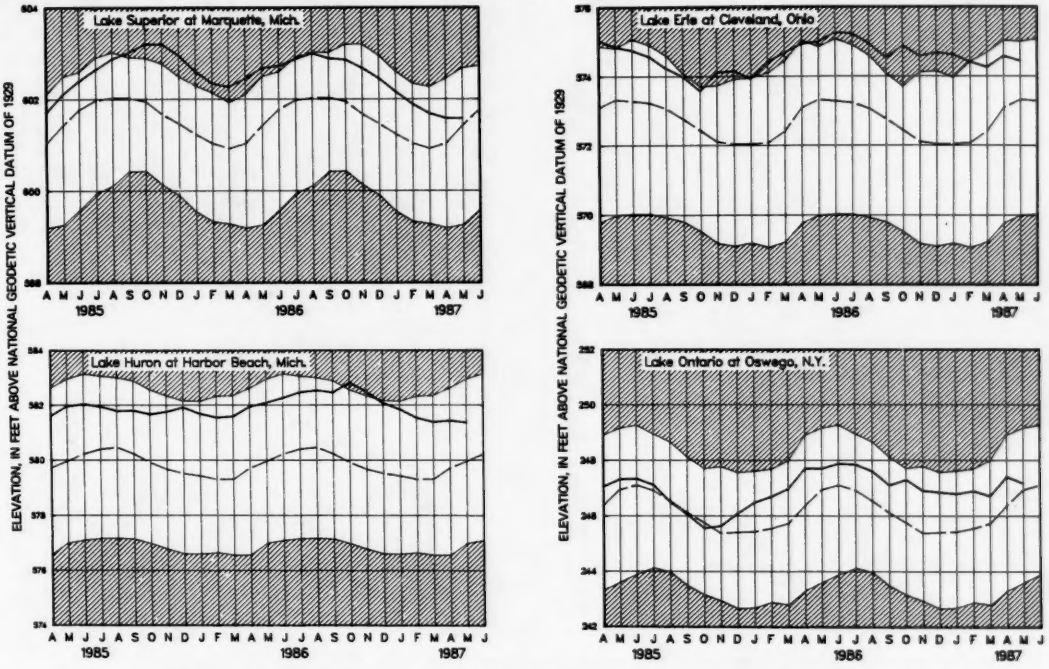
Percentage of Normal Precipitation maps are on page 12. The May 30 Crop Moisture and Drought Severity maps (page 13) show the differences between short-term and long-term soil moisture. June through August outlook maps for both temperature and precipitation are on page 19.

Contents of 85 percent of reporting reservoirs were near or above average for the end of May, compared with 87 percent for the end of April. Most reporting reservoirs in Colorado, Oklahoma, Texas, New Mexico, and Arizona had contents significantly above average for the end of May. The only reservoir with both a significant decline in contents during the month and significantly below-average contents for the end of the month was Shasta Lake in California. Contents of the Baltimore Municipal System were within 5 percent of the monthend average, ending 20 months of below-average contents beginning July 1985. Graphs of contents for seven reservoirs are shown on page 8 with contents for the 100 reporting reservoirs given on page 9.

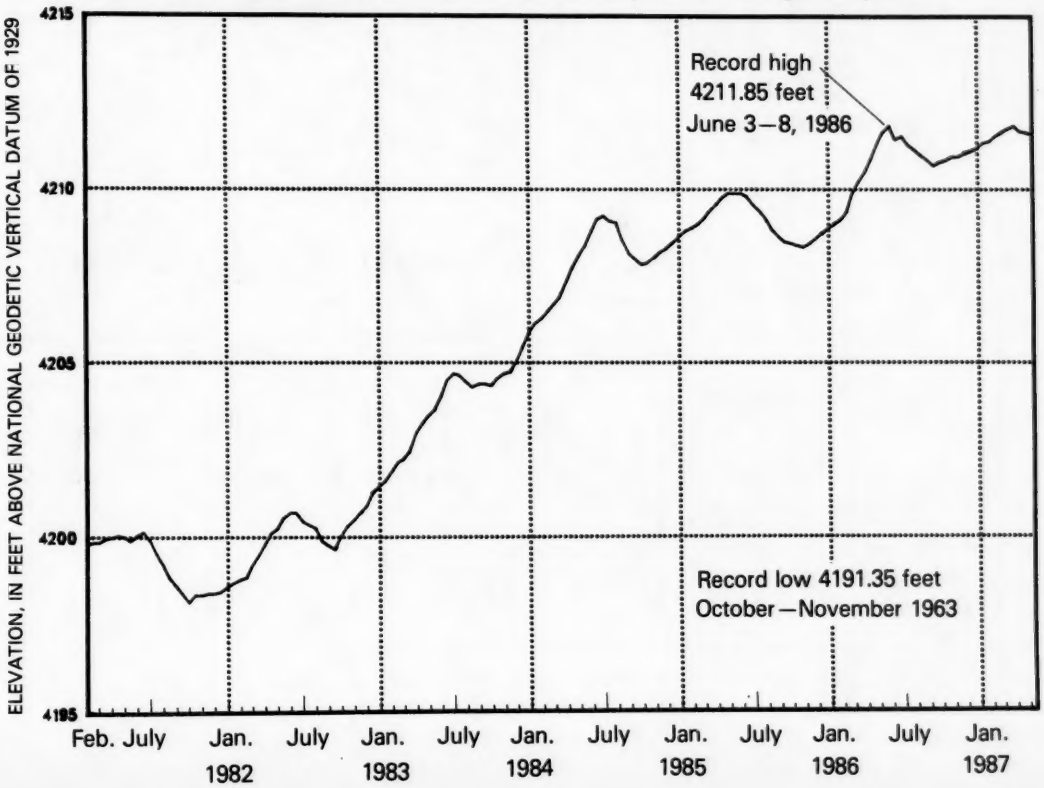
The combined flow of the 3 largest rivers in the lower 48 States—Mississippi, St. Lawrence, and Columbia—averaged a below-normal 1,255,600 cfs during May, 17.2 percent below median and 10.1 percent below last month's flow. Mean flow of the Mississippi River at Vicksburg, Mississippi, decreased by about 40 percent from that for April and was in the below-normal range for only the third time in the last 56 months, the other two times being in April and May 1986. Mean flow of the Columbia River at The Dalles, Oregon, was in the normal range for the third consecutive month. Mean flow of the St. Lawrence River at Cornwall, Ontario, was in the above-normal range for the 28th consecutive month and was the 3rd highest for May in 127 years of record. Flow hydrographs for both the combined and individual flows of the "Big 3" are shown on page 10. May flows of these three rivers are given in the Flow of Large Rivers table on page 11. Dissolved solids and water temperatures at five large river stations are given on page 10.

GREAT LAKES ELEVATIONS

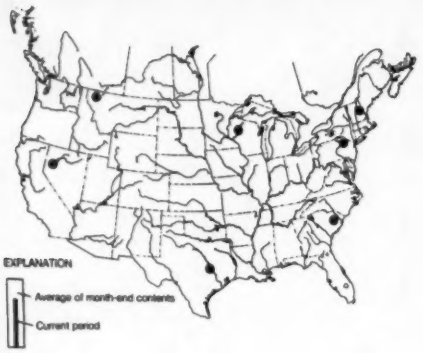
Unshaded area indicates range between highest and lowest record for the month. Dashed line indicates median of monthly values for reference period, 1951–80. Heavy line indicates mean for current period. Data from National Ocean Service.

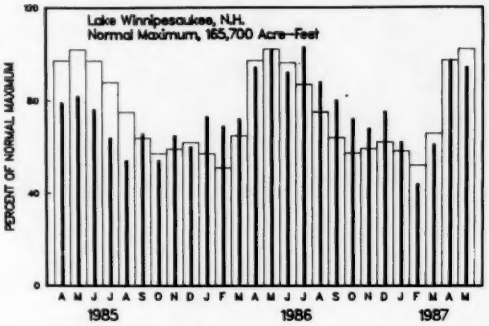

Lake Superior at Marquette, Mich.
Lake Erie at Cleveland, Ohio
Lake Huron at Harbor Beach, Mich.
Lake Ontario at Oswego, N.Y.
ELEVATION, IN FEET ABOVE NATIONAL GEODETIC VERTICAL DATUM OF 1929
A M J J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987

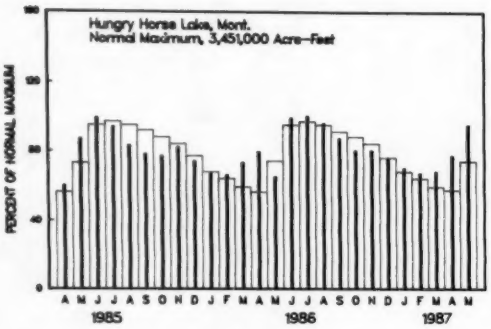
Fluctuations of Great Salt Lake, February 1981 through May 1987

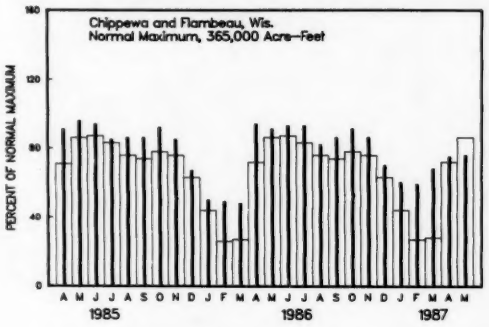


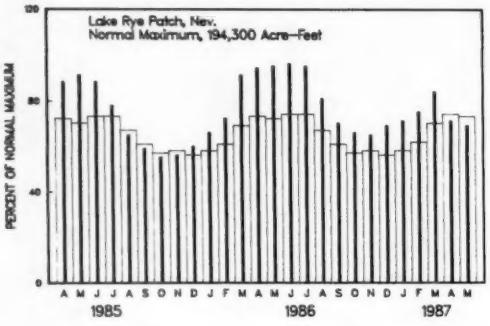
USABLE CONTENTS OF SELECTED RESERVOIRS AND RESERVOIR SYSTEMS




Lake Winnipesaukee, N.H.
Normal Maximum, 165,700 Acre-Feet
PERCENT OF NORMAL MAXIMUM
0
40
80
120
A M J J A S O N D J F M A M J J A S O N D J F M A M
1985
1986
1987






Lake Rye Patch, Nev.
Normal Maximum, 194,300 Acre-Feet
PERCENT OF NORMAL MAXIMUM
0
40
80
120
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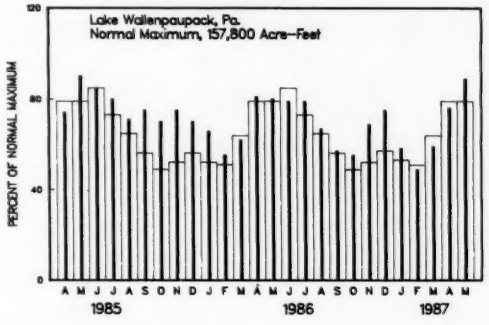
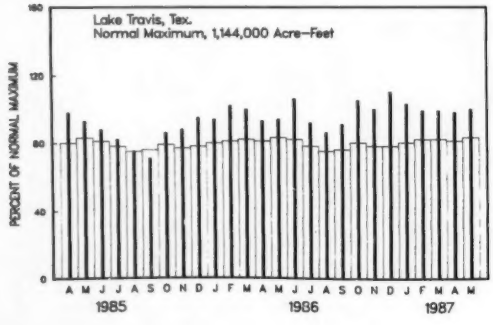
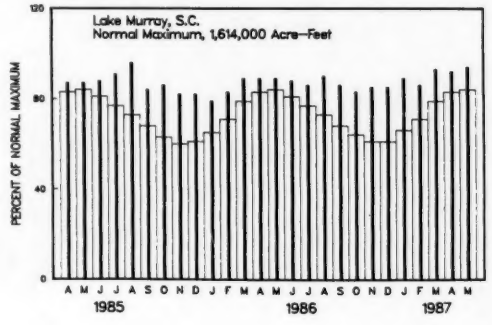
1985
1986
1987


Lake Wallenpaupack, Pa.
Normal Maximum, 157,800 Acre-Feet
PERCENT OF NORMAL MAXIMUM
0
40
80
120
A M J J A S O N D J F M A M J J A S O N D J F M A M
1985
1986
1987




Lake Murray, S.C.
Normal Maximum, 1,614,000 Acre-Feet
PERCENT OF NORMAL MAXIMUM
0
40
80
120
A M J J A S O N D J F M A M J J A S O N D J F M A M
1985
1986
1987

USABLE CONTENTS OF SELECTED RESERVOIRS NEAR END OF MAY 1987

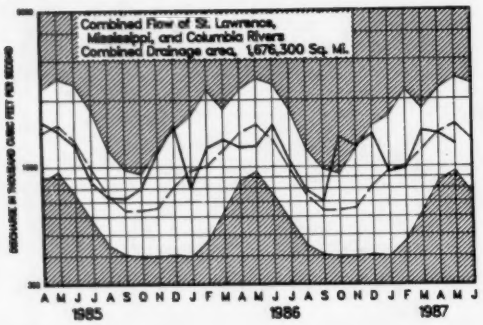
[Contents are expressed in percent of reservoir capacity. The usable storage capacity of each reservoir is shown in the column headed "Normal maximum."]

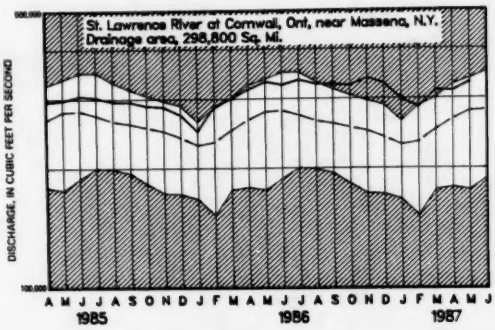
Reservoir Principal uses: F–Flood control I–Irrigation M–Municipal P–Power R–Recreation W–Industrial	Percent of normal maximum				Normal maximum[a] (acre-feet)
	End of May 1987	End of May 1986	Average for end of May	End of Apr. 1987	
NOVA SCOTIA					
Rossignol, Mulgrave, Falls Lake, St. Margaret's Bay, Black, and Ponhook Reservoirs(P)	51	57	78	48	[b]226,300
QUEBEC					
Allard (P)	91	83	88	85	280,600
Gouin (P)	62	75	65	67	6,954,000
MAINE					
Seven reservoir systems (MP)	82	89	90	83	4,107,000
NEW HAMPSHIRE					
First Connecticut Lake (P)	87	90	88	75	76,450
Lake Francis (FPR)	78	72	82	62	99,310
Lake Winnipesaukee (PR)	94	102	102	97	165,700
VERMONT					
Harriman (P)	88	91	87	86	116,200
Somerset (P)	88	86	86	86	57,390
MASSACHUSETTS					
Cobble Mountain and Borden Brook (MP)	95	82	90	96	77,920
NEW YORK					
Great Sacandaga Lake (FPR)	87	100	98	90	786,700
Indian Lake (FMP)	87	103	103	82	103,300
New York City reservoir system (MW)	. . .	100	100	99	1,680,000
NEW JERSEY					
Wanaque (M)	96	97	95	101	85,100
PENNSYLVANIA					
Allegheny (FPR)	49	51	47	50	1,180,000
Pymatuning (FMR)	94	101	99	94	188,000
Raystown Lake (FR)	68	68	62	68	761,900
Lake Wallenpaupack (PR)	89	80	79	76	157,800
MARYLAND					
Baltimore municipal system (M)	91	84	94	87	261,900
NORTH CAROLINA					
Bridgewater (Lake James) (P)	96	92	92	100	288,800
Narrows (Badin Lake) (P)	94	89	99	100	128,900
High Rock Lake (P)	86	73	83	100	234,800
SOUTH CAROLINA					
Lake Murray (P)	94	89	84	92	1,614,000
Lakes Marion and Moultrie (P)	78	80	80	83	1,862,000
SOUTH CAROLINA—GEORGIA					
Clark Hill (FP)	78	56	76	78	1,730,000
GEORGIA					
Burton (PR)	96	100	92	97	104,000
Sinclair (MPR)	85	87	93	88	214,000
Lake Sidney Lanier (FMPR)	66	49	66	65	1,686,000
ALABAMA					
Lake Martin (P)	98	91	95	98	1,375,000
TENNESSEE VALLEY					
Clinch Projects: Norris and Melton Hill Lakes (FPR)	69	52	65	75	2,293,000
Douglas Lake (FPR)	81	41	71	76	1,394,000
Hiwassee Projects: Chatuge, Nottely, Hiwassee, Apalachia, Blue Ridge, Ocoee 3, and Parksville Lakes (FPR)	80	62	83	73	1,012,000
Holston Projects: South Holston, Watauga, Boone, Fort Patrick Henry, and Cherokee Lakes (FPR)	83	64	70	87	2,880,000
Little Tennessee Projects: Nantahala, Thorpe, Fontana, and Chilhowee Lakes (FPR)	80	55	83	75	1,478,000
WISCONSIN					
Chippewa and Flambeau (PR)	76	91	86	75	365,000
Wisconsin River (21 reservoirs) (PR)	51	79	82	50	399,000
MINNESOTA					
Mississippi River headwater system (FMR)	40	53	37	33	1,640,000
NORTH DAKOTA					
Lake Sakakawea (Garrison) (FIPR)	88	84	85	87	22,700,000
SOUTH DAKOTA					
Angostura (I)	95	94	90	95	127,600
Belle Fourche (I)	97	86	74	96	185,200
Lake Francis Case (FIP)	86	87	82	81	4,834,000
Lake Oahe (FIP)	94	100	. . .	95	22,530,000
Lake Sharpe (FIP)	100	101	100	100	1,725,000
Lewis and Clark Lake (FIP)	77	76	84	74	432,000
NEBRASKA					
Lake McConaughy (IP)	85	88	80	82	1,948,000
OKLAHOMA					
Eufaula (FRP)	122	113	97	97	2,378,000
Keystone (FPR)	168	107	107	86	661,000
Tenkiller Ferry (FPR)	105	109	103	104	628,200
Lake Altus (FIMR)	107	31	65	100	133,000
Lake O'The Cherokees (FPR)	100	94	94	94	1,492,000
OKLAHOMA—TEXAS					
Lake Texoma (FMPRW)	113	100	103	97	2,722,000
TEXAS					
Bridgeport (IMW)	99	90	55	100	386,400
Canyon (FMR)	99	99	82	99	385,600
International Amistad (FIMPW)	92	42	78	87	3,497,000
International Falcon (FIMPW)	77	28	64	85	2,668,000
Livingston (IMW)	101	105	92	100	1,788,000
Possum Kingdom (IMPRW)	67	92	98	67	570,200
Red Bluff (PI)	86	19	26	89	307,000
Toledo Bend (P)	89	97	93	91	4,472,000
Twin Buttes (FIM)	71	11	30	68	177,800
Lake Kemp (IMW)	97	93	90	101	268,000
Lake Meredith (FWM)	32	28	36	30	796,900
Lake Travis (FIMPRW)	100	94	83	98	1,144,000
MONTANA					
Canyon Ferry (FIMPR)	79	80	80	77	2,043,000
Fort Peck (FPR)	86	80	86	85	18,910,000
Hungry Horse (FIPR)	95	65	74	77	3,451,000
WASHINGTON					
Ross (PR)	75	71	57	30	1,052,000
Franklin D. Roosevelt Lake (IP)	83	63	73	89	5,022,000
Lake Chelan (PR)	76	90	73	30	676,100
Lake Cushman (PR)	98	102	95	84	359,500
Lake Merwin (P)	99	104	104	103	245,600
IDAHO					
Boise River (4 reservoirs) (FIP)	70	81	82	67	1,235,000
Coeur d'Alene Lake (P)	96	96	124	87	238,500
Pend Oreille Lake (FP)	85	48	81	56	1,561,000
IDAHO—WYOMING					
Upper Snake River (8 reservoirs) (MP)	80	62	79	71	4,401,000
WYOMING					
Boysen (FIP)	82	64	66	72	802,000
Buffalo Bill (IP)	78	70	74	68	421,300
Keyhole (F)	48	39	50	45	193,800
Pathfinder, Seminoe, Alcova, Kortes, Glendo, and Guernsey Reservoirs (I)	81	78	62	79	3,056,000
COLORADO					
John Martin (FIR)	114	59	18	97	364,400
Taylor Park (IR)	70	59	70	51	106,200
Colorado–Big Thompson project (I)	84	75	64	80	730,300
COLORADO RIVER STORAGE PROJECT					
Lake Powell; Flaming Gorge, Fontenelle, Navajo, and Blue Mesa Reservoirs (IFPR)	100	87	. . .	100	31,620,000
UTAH—IDAHO					
Bear Lake (IPR)	79	95	70	79	1,421,000
CALIFORNIA					
Folsom (FIP)	74	88	88	71	1,000,000
Hetch Hetchy (MP)	78	68	70	44	360,400
Isabella (FIR)	48	89	49	42	568,100
Pine Flat (FI)	79	82	73	72	1,001,000
Clair Engle Lake (Lewiston) (P)	95	96	91	90	2,438,000
Lake Almanor (P)	92	106	67	88	1,036,000
Lake Berryessa (FIMW)	83	98	88	86	1,600,000
Millerton Lake (FI)	63	61	78	48	503,200
Shasta Lake (FIPR)	85	93	91	93	4,377,000
CALIFORNIA—NEVADA					
Lake Tahoe (IPR)	71	93	69	69	744,600
NEVADA					
Rye Patch (I)	69	95	73	71	194,300
ARIZONA—NEVADA					
Lake Mead and Lake Mohave (FIMP)	91	92	72	92	27,970,000
ARIZONA					
San Carlos (IP)	81	90	28	85	935,100
Salt and Verde River system (IMPR)	98	94	54	99	2,019,100
NEW MEXICO					
Conchas (FIR)	100	78	79	100	330,100
Elephant Butte and Caballo (FIPR)	94	93	36	94	2,442,000

[a] 1 acre-foot = 0.04356 million cubic feet = 0.326 million gallons = 0.504 cubic feet per second day.
[b] Thousands of kilowatt-hours (the potential electric power that could be generated by the volume of water in storage).

HYDROGRAPHS FOR THE "BIG THREE" RIVERS

Unshaded area indicates range between highest and lowest record for the month. Dashed line indicates median of monthly values for reference period, 1951–80. Heavy line indicates mean for current period.


Combined Flow of St. Lawrence, Mississippi, and Columbia Rivers
Combined Drainage area, 1,676,300 Sq. Mi.
A M J J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987


St. Lawrence River at Cornwall, Ont, near Massena, N.Y.
Drainage area, 298,800 Sq. Mi.
DISCHARGE, IN CUBIC FEET PER SECOND
A M J J A S O N D J F M A M J J A S O N D J F M A M J
1985
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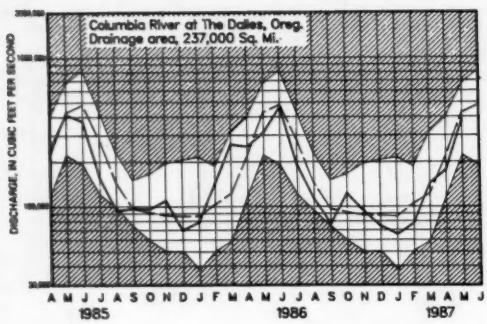
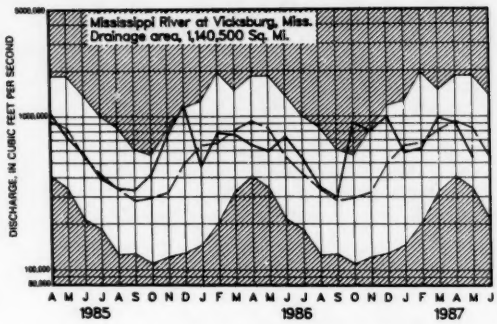

Columbia River at The Dalles, Oreg.
Drainage area, 237,000 Sq. Mi.
DISCHARGE, IN CUBIC FEET PER SECOND
A M J J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987


Mississippi River at Vicksburg, Miss.
Drainage area, 1,140,500 Sq. Mi.
DISCHARGE, IN CUBIC FEET PER SECOND
A M J J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987

Provisional data; subject to revision

DISSOLVED SOLIDS AND WATER TEMPERATURES, FOR MAY 1987, AT DOWNSTREAM SITES ON FIVE LARGE RIVERS

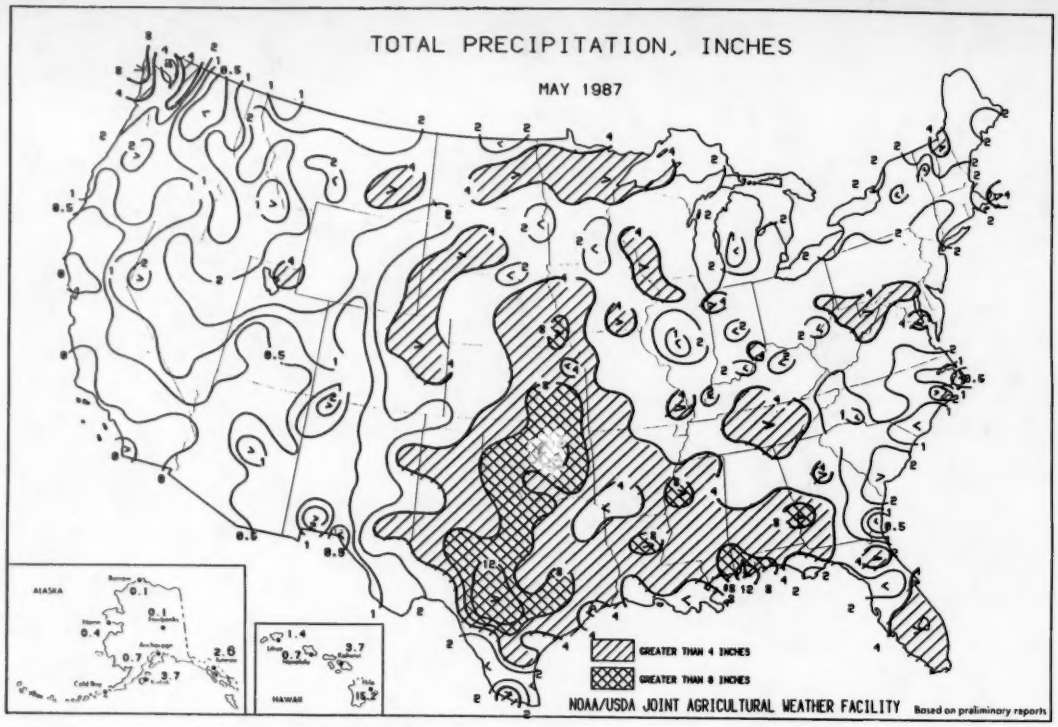
Station number	Station name	May data of following calendar years	Stream discharge during month	Dissolved-solids concentration[a]		Dissolved-solids discharge[a]			Water temperature[b]		
			Mean (cfs)	Minimum (mg/L)	Maximum (mg/L)	Mean	Minimum	Maximum	Mean in °C	Minimum, in °C	Maximum, in °C
						(tons per day)					
01463500	Delaware River at Trenton, N.J. (Morrisville, Pa.).	1987	7,579	100	119	2,244	1,731	3,420	18.0	11.5	26.0
		1945–86	15,280	50	123	....	930	21,790	...	10.0	28.5
		(Extreme yr)		(1946)	(1978)		(1965)	(1984)			
			[c]12,650								
07289000	Mississippi River at Vicksburg, Miss.	1987	544,600	229	295	355,800	270,700	480,400	23.5	19.0	27.0
		1976–86	868,000	178	290	502,400	176,000	954,000	20.5	14.5	26.0
		(Extreme yr)		(1977)	(1982)		(1977)	(1983)			
			[c]838,200								
03612500	Ohio River at lock and dam 53, near Grand Chain, Ill. (streamflow station at Metropolis, Ill.).	1987	169,000	163	195	....	39,200	186,000	...	15.0	20.0
		1955–86	358,600	124	287	....	25,500	466,000	...	6.5	25.0
		(Extreme yr)		(1983)	(1979)		(1976)	(1984)			
			[c]296,000								
06934500	Missouri River at Hermann, Mo. (60 miles west of St. Louis, Mo.).	1987	122,000	370	438	136,000	107,000	190,000	18.5	13.0	24.0
		1976–86	127,200	211	520	117,200	44,500	272,000	19.0	13.0	24.5
		(Extreme yr)		(1978)	(1981)		(1977)	(1983)			
			[c]92,040								
14128910	Columbia River at Warrendale, Oreg. (streamflow station at The Dalles, Oreg.).	1987	232,000	88	108	61,000	41,300	75,200	13.5	11.5	14.5
		1976–86	262,100	67	144	67,600	37,500	102,000	12.5	9.5	16.5
		(Extreme yr)		(1976)	(1977)		(1977)	(1983)			
			[c]427,700								

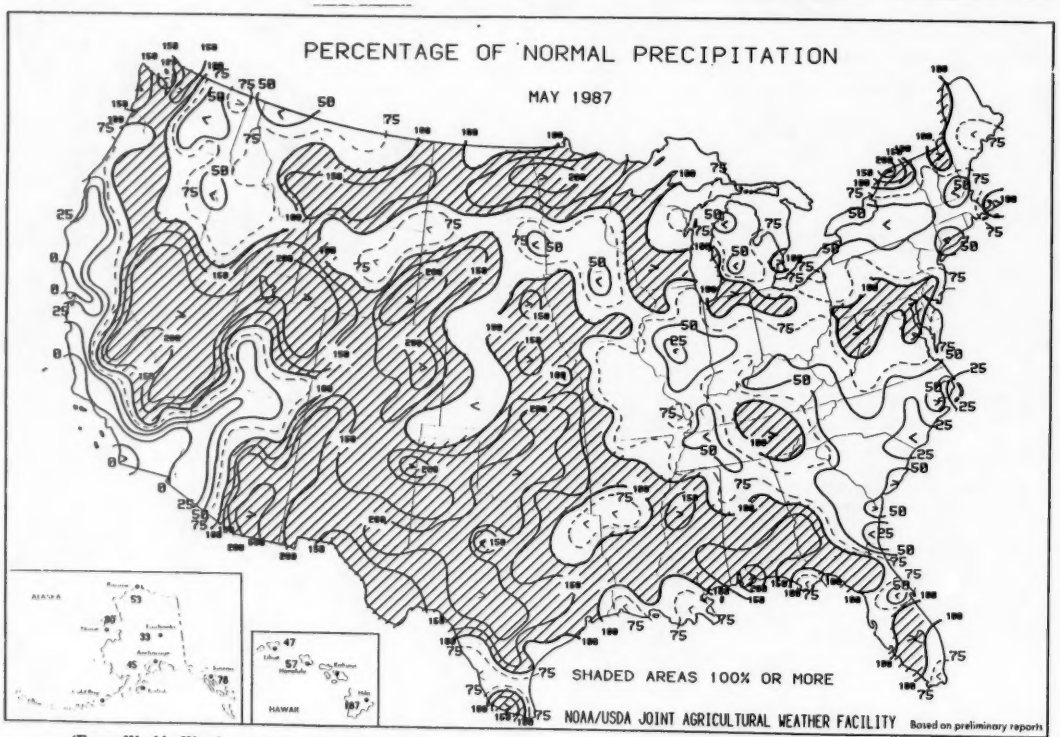
[a]Dissolved-solids concentrations, when not analyzed directly, are calculated on basis of measurements of specific conductance.
[b]To convert °C to °F: [(1.8 X °C) + 32] = °F.
[c]Median of monthly values for 30-year reference period, water years 1951–80, for comparison with data for current month.

FLOW OF LARGE RIVERS DURING MAY 1987

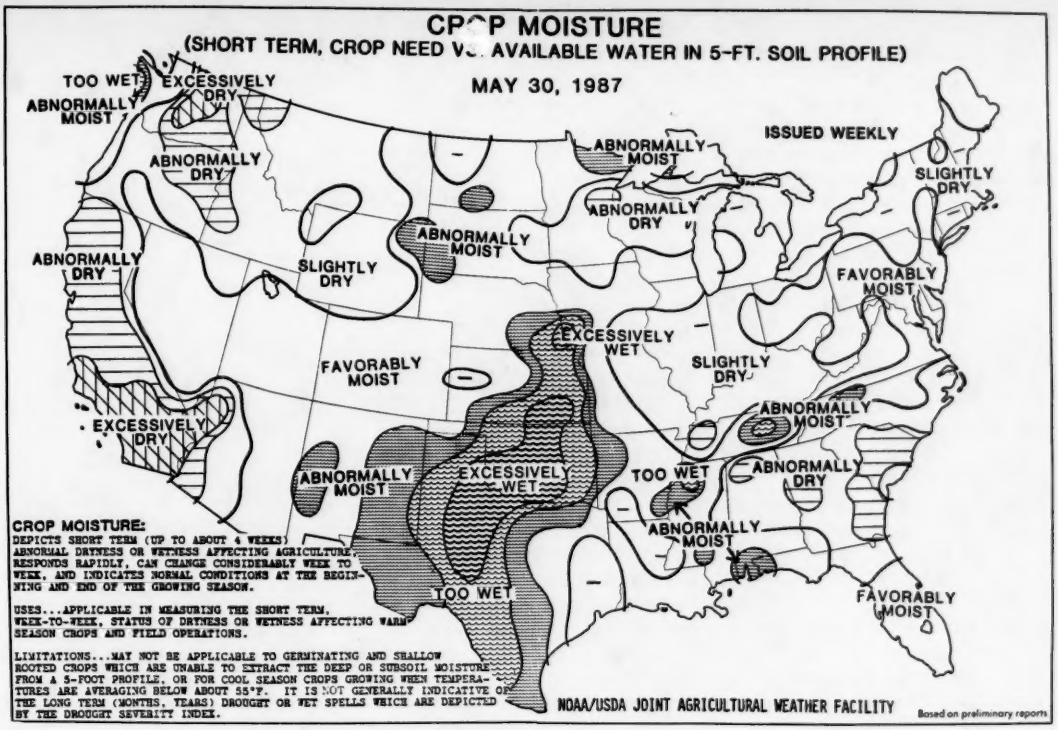
Station number	Stream and place of determination	Drainage area (square miles)	Average discharge through September 1980 (cubic feet per second)	May 1987					
				Monthly mean discharge (cubic feet per second)	Percent of median monthly discharge, 1951—80	Change in discharge from previous month (percent)	Discharge near end of month		
							Cubic feet per second	Million gallons per day	Date
01014000	St. John River below Fish River at Fort Kent, Maine	5,690	9,647	6,754	20	−84	4,481	2,896	31
01318500	Hudson River at Hadley, N.Y.	1,664	2,909	1,460	29	−84	1,310	846	31
01357500	Mohawk River at Cohoes, N.Y.	3,456	5,734	1,790	27	−89	1,300	840	31
01463500	Delaware River at Trenton, N.J.	6,780	11,750	7,579	60	−74	5,910	3,819	31
01570500	Susquehanna River at Harrisburg, Pa.	24,100	34,530	25,280	60	−69	16,800	10,860	27
01646500	Potomac River near Washington, D.C.	11,560	[1]11,490	[1]15,400	110	−67	8,120	5,248	31
02105500	Cape Fear River at William O. Huske Lock near Tarheel, N.C.	4,810	5,005	2,700	80	−73	1,400	900	31
02131000	Pee Dee River at Peedee, S.C.	8,830	9,851	13,000	171	−39	7,420	4,795	31
02226000	Altamaha River at Doctortown, Ga.	13,600	13,880	7,221	59	−71	8,750	5,655	29
02320500	Suwannee River at Branford, Fl.	7,880	6,987	8,540	129	−56	7,330	4,740	31
02358000	Apalachicola River at Chattahoochee, Fl.	17,200	22,570	15,400	76	−44	15,400	9,950	31
02467000	Tombigbee River at Demopolis lock and dam near Coatopa, Ala.	15,400	23,300	7,314	33	−49	6,600	4,270	31
02489500	Pearl River near Bogalusa, La.	6,630	9,768	7,677	74	+10	7,060	4,562	31
03049500	Allegheny River at Natrona, Pa.	11,410	[1]19,480	[1]15,130	71	−65	8,590	5,551	26
03085000	Monongahela River at Braddock, Pa.	7,337	[1]12,510	[1]9,850	70	−67	16,300	10,530	20
03193000	Kanawha River at Kanawha Falls, W.Va.	8,367	12,590	14,610	113	−71	15,000	9,700	28
03234500	Scioto River at Higby, Ohio.	5,131	4,547	2,934	62	−63	6,800	4,390	29
03294500	Ohio River at Louisville, Ky.[2]	91,170	11,600	74,000	56	−77	86,700	56,040	31
03377500	Wabash River at Mount Carmel, Ill.	28,635	27,220	12,080	38	−57	13,600	8,790	29
03469000	French Broad River below Douglas Dam, Tenn.	4,543	6,798	5,839	87	−59	. . .	. . .	. .
04084500	Fox River at Rapide Croche Dam, near Wrightstown, Wis.[2]	6,150	4,163	4,285	75	−4	6,530	4,220	31
04264331	St. Lawrence River at Cornwall, Ontario–near Massena, N.Y.[3]	298,800	242,700	329,000	118	+5	317,000	205,000	31
02NG001	St. Maurice River at Grand Mere, Quebec	16,300	25,150	10,500	15	−79	14,900	9,630	31
05082500	Red River of the North at Grand Forks, N.Dak.	30,100	2,551	3,045	81	−60	6,230	4,026	28
05133500	Rainy River at Manitou Rapids, Minn.	19,400	11,830	8,410	46	−8	17,300	11,180	26
05330000	Minnesota River near Jordan, Minn.	16,200	3,402	2,990	54	−54	3,250	2,100	31
05331000	Mississippi River at St. Paul, Minn.	36,800	[1]10,610	10,300	46	−35	21,500	13,900	31
05365500	Chippewa River at Chippewa Falls, Wis.	5,600	5,100	1,484	24	−44	2,100	1,360	29
05407000	Wisconsin River at Muscoda, Wis.	10,300	8,617	5,987	54	−23	5,260	3,399	31
05446500	Rock River near Joslin, Ill.	9,551	5,873	8,340	123	+6	7,500	4,850	31
05474500	Mississippi River at Keokuk, Iowa.	119,000	62,620	56,760	59	−30	67,200	43,430	31
06214500	Yellowstone River at Billings, Mont.	11,796	7,038	10,500	79	+182	15,900	10,280	29
06934500	Missouri River at Hermann, Mo.	524,200	79,490	122,200	133	−32	120,000	78,000	29
07289000	Mississippi River at Vicksburg, Miss.[4]	1,140,500	576,600	544,600	65	−40	360,000	233,000	26
07331000	Washita River near Dickson, Okla.	7,202	1,368	10,500	605	+192	64,200	41,490	31
08276500	Rio Grande below Taos Junction Bridge, near Taos, N.Mex.	9,730	725	6,020	679	+125	3,000	1,900	31
09315000	Green River at Green River, Utah.	44,850	6,298	10,780	93	+70	. . . .	. . . .	. . .
11425500	Sacramento River at Verona, Calif.	21,257	18,820	9,317	53	−11	. . . .	. . . .	. . .
13269000	Snake River at Weiser, Idaho.	69,200	18,050	10,200	39	−4	11,200	7,240	31
13317000	Salmon River at White Bird, Idaho.	13,550	11,250	17,600	56	+71	11,500	7,430	31
13342500	Clearwater River at Spalding, Idaho.	9,570	15,480	26,500	52	+70	9,270	5,991	31
14105700	Columbia River at The Dalles, Oreg.[5]	237,000	[1]193,100	[1]382,000	89	+116	195,500	126,400	27
14191000	Willamette River at Salem, Oreg.	7,280	[1]23,510	[1]10,000	43	−39	6,940	4,485	27
15515500	Tanana River at Nenana, Alaska.	25,600	23,460	18,200	62	+136	17,500	11,310	31
08MF005	Fraser River at Hope, British Columbia.	83,800	96,290	180,100	99	+130	156,100	100,900	29

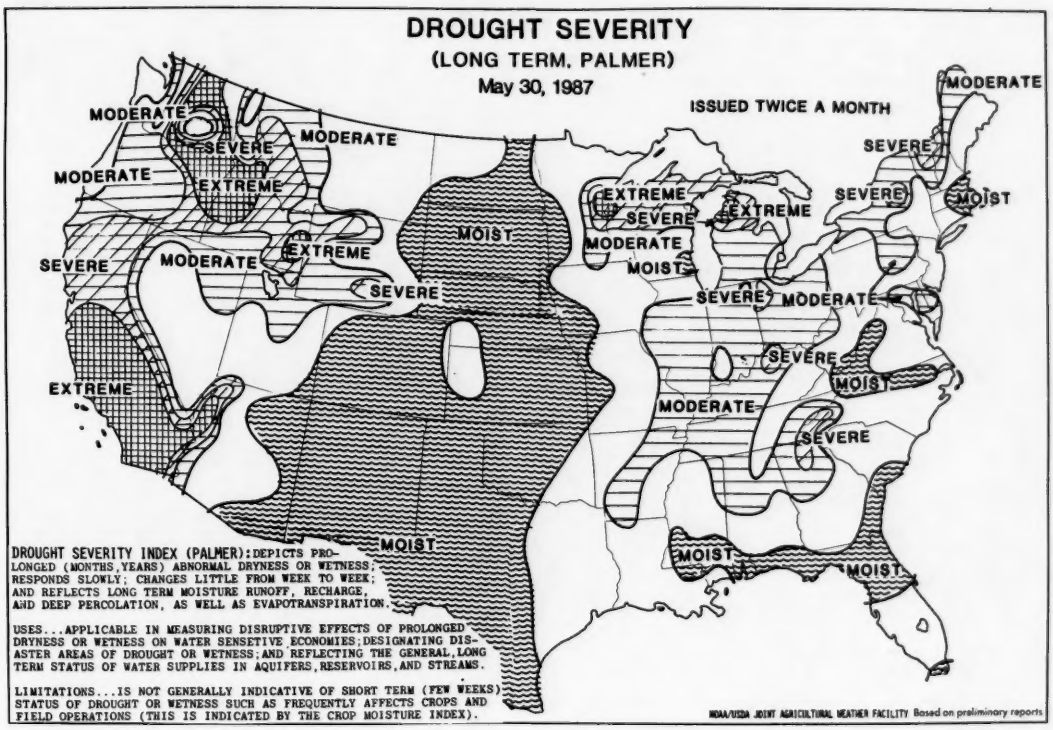
[1]Adjusted.
[2]Records furnished by Corps of Engineers.
[3]Records furnished by Buffalo District, Corps of Engineers, through International St. Lawrence River Board of Control. Discharges shown are considered to be the same as discharge at Ogdensburg, N.Y. when adjusted for storage in Lake St. Lawrence.
[4]Records of daily discharge computed jointly by Corps of Engineers and Geological Survey.
[5]Discharge determined from information furnished by Bureau of Reclamation, Corps of Engineers, and Geological Survey.





(From *Weekly Weather and Crop Bulletin* prepared and published by the NOAA/USDA Joint Agricultural Weather Facility)


CROP MOISTURE
(SHORT TERM, CROP NEED VS. AVAILABLE WATER IN 5-FT. SOIL PROFILE)
MAY 30, 1987
ISSUED WEEKLY
TOO WET
EXCESSIVELY DRY
ABNORMALLY MOIST
ABNORMALLY DRY
SLIGHTLY DRY
FAVORABLY MOIST
EXCESSIVELY WET
CROP MOISTURE:
DEPICTS SHORT TERM (UP TO ABOUT 4 WEEKS) ABNORMAL DRYNESS OR WETNESS AFFECTING AGRICULTURE, RESPONDS RAPIDLY, CAN CHANGE CONSIDERABLY WEEK TO WEEK, AND INDICATES NORMAL CONDITIONS AT THE BEGINNING AND END OF THE GROWING SEASON.
USES...APPLICABLE IN MEASURING THE SHORT TERM, WEEK-TO-WEEK, STATUS OF DRYNESS OR WETNESS AFFECTING WARM SEASON CROPS AND FIELD OPERATIONS.
LIMITATIONS...MAY NOT BE APPLICABLE TO GERMINATING AND SHALLOW ROOTED CROPS WHICH ARE UNABLE TO EXTRACT THE DEEP OR SUBSOIL MOISTURE FROM A 5-FOOT PROFILE, OR FOR COOL SEASON CROPS GROWING WHEN TEMPERATURES ARE AVERAGING BELOW ABOUT 55°F. IT IS NOT GENERALLY INDICATIVE OF THE LONG TERM (MONTHS, YEARS) DROUGHT OR WET SPELLS WHICH ARE DEPICTED BY THE DROUGHT SEVERITY INDEX.
NOAA/USDA JOINT AGRICULTURAL WEATHER FACILITY
Based on preliminary reports


DROUGHT SEVERITY
(LONG TERM, PALMER)
May 30, 1987
ISSUED TWICE A MONTH
MODERATE
SEVERE
EXTREME
MOIST
DROUGHT SEVERITY INDEX (PALMER): DEPICTS PROLONGED (MONTHS, YEARS) ABNORMAL DRYNESS OR WETNESS; RESPONDS SLOWLY; CHANGES LITTLE FROM WEEK TO WEEK; AND REFLECTS LONG TERM MOISTURE RUNOFF, RECHARGE, AND DEEP PERCOLATION, AS WELL AS EVAPOTRANSPIRATION.
USES...APPLICABLE IN MEASURING DISRUPTIVE EFFECTS OF PROLONGED DRYNESS OR WETNESS ON WATER SENSETIVE ECONOMIES; DESIGNATING DISASTER AREAS OF DROUGHT OR WETNESS; AND REFLECTING THE GENERAL, LONG TERM STATUS OF WATER SUPPLIES IN AQUIFERS, RESERVOIRS, AND STREAMS.
LIMITATIONS...IS NOT GENERALLY INDICATIVE OF SHORT TERM (FEW WEEKS) STATUS OF DROUGHT OR WETNESS SUCH AS FREQUENTLY AFFECTS CROPS AND FIELD OPERATIONS (THIS IS INDICATED BY THE CROP MOISTURE INDEX).
NOAA/USDA JOINT AGRICULTURAL WEATHER FACILITY Based on preliminary reports

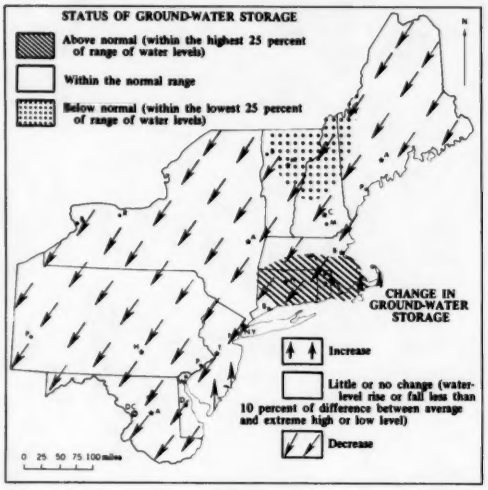
(From *Weekly Weather and Crop Bulletin* prepared and published by the NOAA/USDA Joint Agricultural Weather Facility)

GROUND-WATER CONDITIONS DURING MAY 1987

Ground-water levels declined seasonally in nearly the entire Northeast. (See map.) Levels fell only slightly on Long Island, New York, and rose in southeastern Massachusetts and southern New Jersey. Water levels near the end of the month were generally within the normal range for the end of May. Exceptions were above-average levels in Rhode Island and adjacent parts of Connecticut and Massachusetts, including the highest level of record in 25 years at one key observation well in Cape Cod. Levels were below average in northern New Hampshire and Vermont, adjacent Maine, and also at wells in eastern New York State. A few observation wells had lowest May water levels in more than 20 years of record.

In the Southeast, ground-water levels rose in Louisiana, but declined seasonally in West Virginia, Kentucky, and North Carolina, and declined in most wells in Mississippi and Georgia. Net water-level changes were mixed in Virginia and Arkansas. Water levels were above long-term averages in Kentucky and North Carolina, below average in Arkansas, and mixed with respect to average in West Virginia, Virginia, and Louisiana. New low water levels for May were reached in Memphis, Tennessee, and Stuttgart, Arkansas. The new low in the Stuttgart well is the fifth consecutive low monthend level in this well.

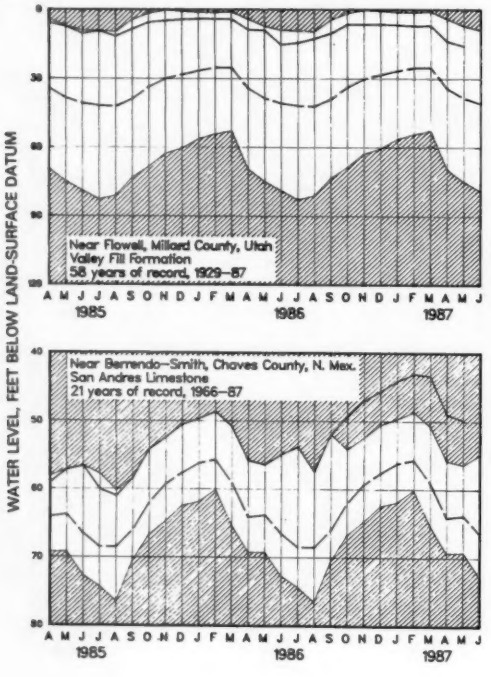
In the central and western Great Lakes States, ground-water levels declined seasonally in all reporting wells. Water levels were below average in Michigan, near or below average in Ohio, and below average in most wells in Iowa. Levels were mixed with respect to average in Minnesota.

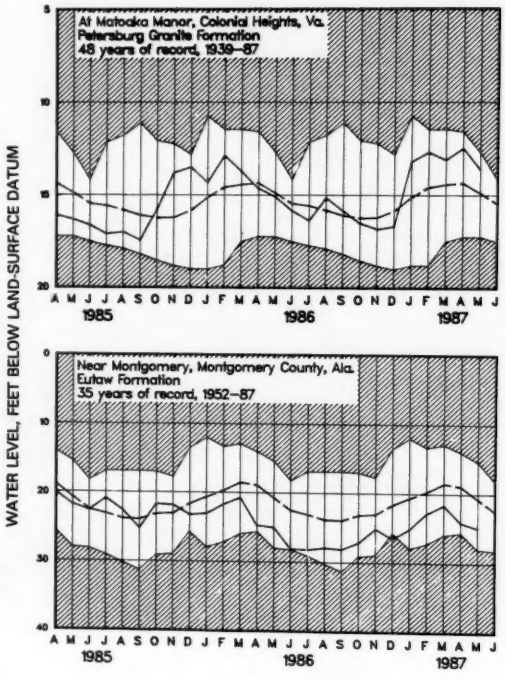

STATUS OF GROUND-WATER STORAGE
Above normal (within the highest 25 percent of range of water levels)
Within the normal range
Below normal (within the lowest 25 percent of range of water levels)
N
CHANGE IN GROUND-WATER STORAGE
Increase
Little or no change (water-level rise or fall less than 10 percent of difference between average and extreme high or low level)
Decrease
0 25 50 75 100 miles

Map showing ground-water storage near end of May and change in ground-water storage from end of April to end of May.

MONTH-END GROUND-WATER LEVELS IN KEY WELLS

Unshaded area indicates range between highest and lowest record for the month. Dashed line indicates average of monthly levels in previous years. Heavy line indicates level for current period.


WATER LEVEL, FEET BELOW LAND-SURFACE DATUM
Near Flowell, Millard County, Utah
Valley Fill Formation
58 years of record, 1929–87
Near Berrendo–Smith, Chaves County, N. Mex.
San Andres Limestone
21 years of record, 1966–87
A M J J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987


WATER LEVEL, FEET BELOW LAND-SURFACE DATUM
At Matoaka Manor, Colonial Heights, Va.
Petersburg Granite Formation
48 years of record, 1939–87
Near Montgomery, Montgomery County, Ala.
Eutaw Formation
35 years of record, 1952–87
A M J J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987

In the Western States, ground-water levels showed mixed changes in Washington, Idaho, Nevada, Utah, Kansas, Arizona, New Mexico, and Texas. Levels declined in North Dakota, Nebraska, and southern California. Water levels were mixed with respect to long-term averages in Washington, Idaho, North Dakota, Nebraska, southern California, Nevada, Utah, Kansas, New Mexico, and Texas. Levels were below average in Arizona. New high ground-water levels for May were recorded in Nevada, Kansas, and New Mexico. New low May levels were established in Nevada, Kansas, New Mexico, and Texas.

Provisional data; subject to revision

WATER LEVELS IN KEY OBSERVATION WELLS IN SOME REPRESENTATIVE AQUIFERS IN THE CONTERMINOUS UNITED STATES—MAY 1987

Aquifer and Location	Water level in feet with reference to land-surface datum	Departure from average in feet	Net change in water level in feet since:		Year records began	Remarks
			Last month	Last year		
Glacial drift at Hanska, south-central Minnesota.	−7.22	−1.72	−0.79	−3.02	1942	
Glacial drift at Roscommon in north-central part of Lower Peninsula, Michigan.	−5.04	−1.12	−0.24	−1.50	1935	
Glacial drift at Marion, Iowa	−3.55	+0.11	−0.25	−1.27	1941	
Glacial drift at Princeton in northwestern Illinois.	−7.75	+0.18	−0.27	−1.13	1943	
Petersburg Granite, southeastern Piedmont near Fall Zone, Colonial Heights, Virginia.	−13.63	+1.21	−1.16	+1.46	1939	
Glacial outwash sand and gravel, Louisville, Kentucky (U.S. well no. 2).	−18.69	+6.05	−0.11	−1.19	1946	
500-foot sand aquifer near Memphis, Tennessee (U.S. well no. 2).	−105.80	−16.64	−0.41	−1.07	1941	May low.
Weathered granite, Mocksville area, Davie County, western Piedmont, North Carolina.	−16.77	+2.50	−1.64	+2.71	1932	
Sparta Sand in Pine Bluff industrial area, Arkansas.	−229.50	−22.07	+0.05	−10.35	1958	
Eutaw Formation in the City of Montgomery, Alabama (U.S. well no. 4).	−24.9	−4.4	−0.8	+0.1	1952	
Limestone aquifer on Cockspur Island, Savannah area, Georgia (U.S. well no. 6).	−34.38	−7.75	−1.78	+0.80	1956	
Sand and gravel in Puget Trough, Tacoma, Washington.	−101.06	+8.02	−0.16	−1.28	1952	
Pleistocene glacial outwash gravel, North Pole, northern Idaho (U.S. well no. 3).	−464.4	−3.8	−1.5	−2.9	1929	
Snake River Group: Snake River Plain Aquifer, at Eden, Idaho (U.S. well no. 4).	−121.4	−0.6	+1.2	+1.7	1957	
Alluvial valley fill in Flowell area, Millard County, Utah (U.S. well no. 9).	−15.91	+21.06	−2.0	−6.83	1929	
Alluvial sand and gravel, Platte River Valley, Ashland, Nebraska (U.S. well no. 6).	−3.00	+1.14	−0.83	+0.20	1935	
Alluvial valley fill in Steptoe Valley, Nevada	−6.51	+5.90	+0.03	+0.56	1950	May high.
Pleistocene terrace deposits in Kansas River valley, at Lawrence, northeastern Kansas.	−15.41	+5.15	−0.14	+1.67	1953	May high.
Alluvium and Paso Robles clay, sand, and gravel, Santa Maria, California	−120.05	+20.50	. . .	+7.66	1957	
Valley fill, Elfrida area, Douglas, Arizona (U.S. well no. 15).	−102.6	−21.4	+0.1	+1.8	1951	
Hueco bolson, El Paso area, Texas	−267.52	−18.74	−0.94	−1.34	1965	May low.
Evangeline aquifer, Houston area, Texas	−309.66	−13.46	+0.58	−4.06	1965	

HYDROLOGY, GEOMORPHOLOGY, AND DAM-BREAK MODELING OF THE JULY 15, 1982, LAWN LAKE DAM AND CASCADE LAKE DAM FAILURES, LARIMER COUNTY, COLORADO

The abstract (abridged) and illustrations on the following page are from the report, *Hydrology, geomorphology, and dam-break modeling of the July 15, 1982, Lawn Lake dam and Cascade Lake dam failures, Larimer County, Colorado*, by Robert D. Jarrett and John E. Costa, U.S. Geological Survey Professional Paper 1369, 78 pages, 2 plates, 1986. This report may be purchased for $4.25 from, U.S. Geological Survey, Books and Open-File Reports, Box 25425, Federal Center, Denver, CO 80225 (check or money order payable to U.S. Geological Survey); or from Superintendent of Documents, Government Printing Office, Washington, D.C. 20402 (payable to Superintendent of Documents).

ABSTRACT

At approximately 0530 Mountain Daylight Time on the morning of July15, 1982, Lawn Lake dam, a 26-foot-high earthen dam located in Rocky Mountain National Park, Colorado, failed (see figure 1). The dam released 674 acre-feet of water and an estimated peak discharge of 18,000 cubic feet per second down the Roaring River valley. Three people were killed and damages totaled $31 million. The Colorado State Engineer determined that the probable cause of failure was deterioration of lead caulking used for the connection between the outlet pipe and the gate valve. The resulting leak eroded the earthfill, and progressive piping led to failure of the embankment.

Floodwaters from Lawn Lake dam overtopped a second dam, Cascade Lake dam, located 6.7 miles downstream, which also failed. Cascade Lake dam, a 17-foot-high concrete gravity dam, 12.1 acre-foot capacity dam, failed by toppling with 4.2 feet of water flowing over its crest. The flood continued down the Fall River into the town of Estes Park, which received extensive damage from the overbank flow.

This report presents the setting, a summary of the causes of the dam failures, the hydrologic data, and geomorphic effects of the flood. Data on dam-breach floods on high-gradient streams are limited. A dam-break computer model was used to evaluate the model's capabilities on high-gradient streams, to enhance and provide supplemental hydrologic information, and to evaluate various hypothetical scenarios of dam-breach development and probable impact of the failure of Cascade Lake dam.

Flood data were obtained at two gaging stations (06732500 Fall River at Estes Park and 06733000 Big Thompson River at Estes Park) and five miscellaneous sites downstream from the Lawn Lake dam. Peak discharges were determined using a variety of indirect methods. Because of extensive scour and erosion along the Roaring River, peak discharges were estimated from the dam-break model. Calculated peak discharges for the flood were 18,000 cubic feet per second from Lawn Lake dam, 12,000 cubic feet per second at Horseshoe Falls where Roaring River joins the Fall River, 7,210 cubic feet per second into Cascade Lake dam at the east end of Horseshoe Park, 16,000 cubic feet per second from the failure of Cascade Lake dam, 13,100 cubic feet per second about 1 mile downstream from Cascade Lake dam, 8,520 cubic feet per second just upstream from Estes Park, 6,550 cubic feet per second for gaging station 06732500 Fall River at Estes Park, and 5,500 cubic feet per second for gaging station 06733000 Big Thompson River at Estes Park (see figure 2). Maximum depths ranged from 6.4 to 23.8 feet; maximum widths ranged from 97 to 1,112 feet; and mean velocities ranged from 3.3 to 12.6 feet per second. Traveltimes of the flood were determined from eyewitness accounts. The leading flood wave took 3.28 hours to travel 12.5 miles (average 3.8 miles per hour). Flood peaks were 2.1 to 30 times the 500-year flood for selected locations along the flood path. Geomorphic and sedimentologic evidence suggest that it probably was the largest flood in these basins, at least since the retreat of the glaciers several thousands of years ago.

Geomorphic effects of the flood resulting from the dam failures were profound. Channels were widened tens of feet and scoured from 5 to 50 feet locally. In the Roaring River valley, alternate river reaches were either scoured or filled, depending on valley slope. Generally, reaches steeper than 7 percent were scoured, and reaches less than 7 percent were filled. In the Roaring River, 56 percent of the channel was scoured, some by as much as 50 feet, and 44 percent was filled with coarse sediments, 2 to 8 feet thick.

An alluvial fan of 42.3 acres, containing 364,600 cubic yards of material, was deposited at the mouth of the Roaring River. The fan has a maximum thickness of 44 feet and an average thickness of 5.3 feet. The largest boulder thought to have moved in the flood, $14 \times 17.5 \times 21$ feet and weighing an estimated 452 tons, was located on the alluvial fan. Down the flow axis, average particle size changes from 7.5-foot boulders to fine sand and silt in a distance of 1,900 feet. The alluvial fan dammed the Fall River, forming a lake of 17 acres upstream from the fan.

Satisfactory results were obtained from the dam-break model, but not without significant difficulties in proper operation of the model. To calibrate the model, Manning n-values between 0.1 and 0.2, or an average of 78 percent greater than field-selected values, were required; subcritical flow was verified. The occurrence of numerous debris dams caused localized backwater, resulting in predominantly subcritical flow. However, when these debris dams broke, flow probably was supercritical for a short distance until another debris dam formed. Without the extensive calibration of the model and the assumption of subcritical flow, results would have been significantly different.

Peak discharges from dam-break modeling reflect water-only discharges; total discharge may have been considerably higher on the Roaring River and on the Fall River immediately downstream from Cascade Lake dam from sediment and debris. At Horseshoe Falls and for a short reach downstream from Cascade Lake dam, geomorphic and sedimentologic evidence indicates the flow temporarily became a turbulent, high-concentration, cohesionless sediment-gravity flow. The sediment and debris may have bulked the peak water flow by 50 to 60 percent. The range of difference of observed and modeled peak discharges varied from $-3,200$ cubic feet per second to 600 cubic feet per second. The range of difference of observed and modeled maximum flood depth was -1.3 to 2.6 feet and averaged 1.0 foot. The range of difference of observed and modeled leading edge of traveltime was -0.4 and 0.15 hour.

Comparisons were made for hypothetical breach widths of (1) 25 feet and (2) 200 feet. They were compared with model results of the actual breach width of 55 feet.

If Cascade Lake dam had not failed (or had not been present), peak discharges would have been reduced by 11,300 cubic feet per second immediately downstream from the dam to 500 cubic feet per second less at Estes Park. Maximum flood depths would have averaged 0.6 foot lower, and the flood wave would have reached Lake Estes 0.3 hour later.

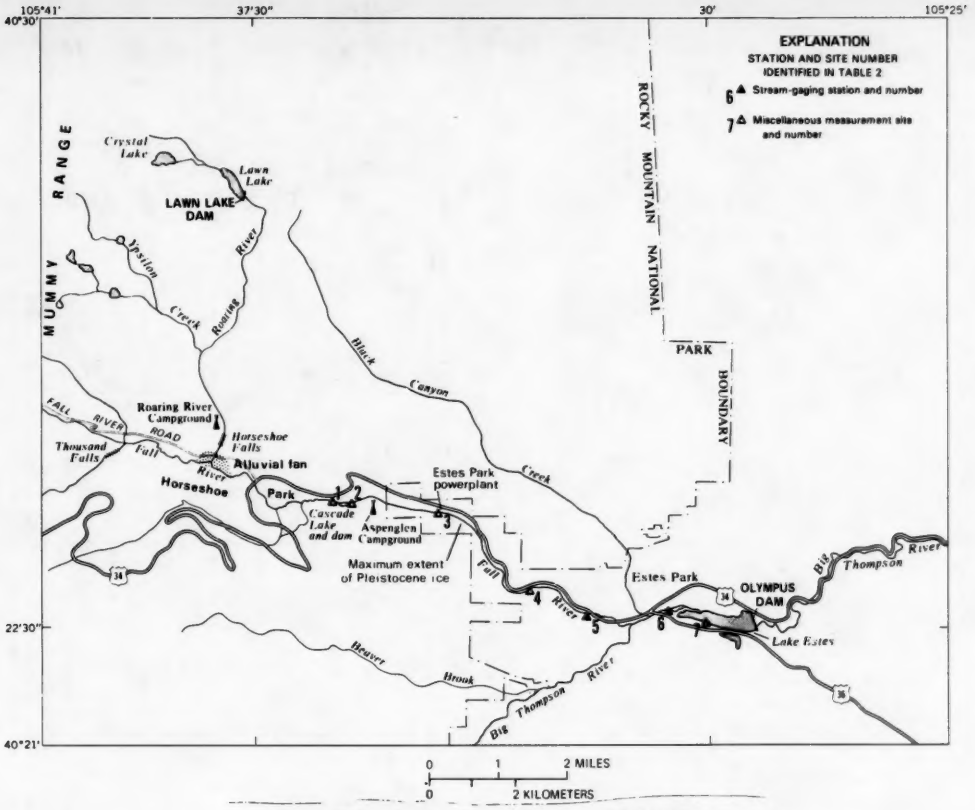


Figure 1. Area between Lawn Lake dam and Lake Estes.

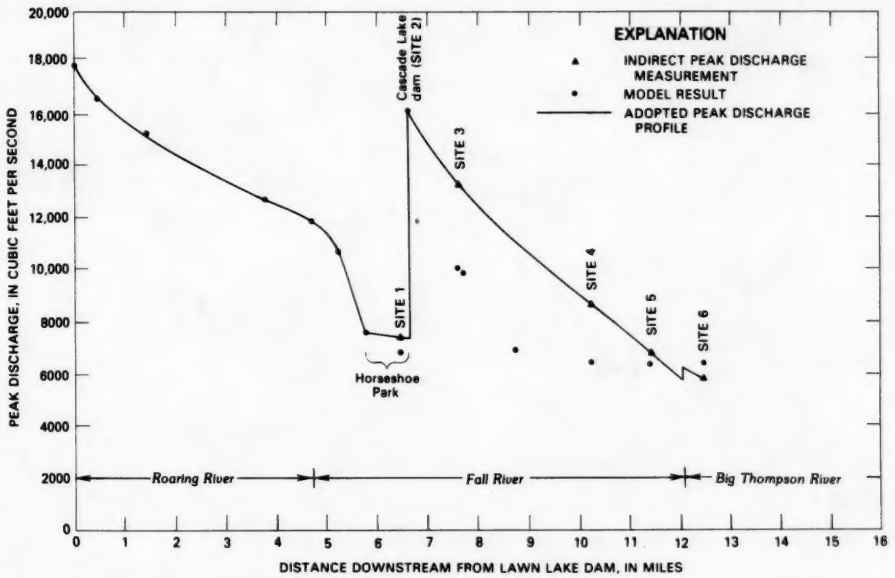
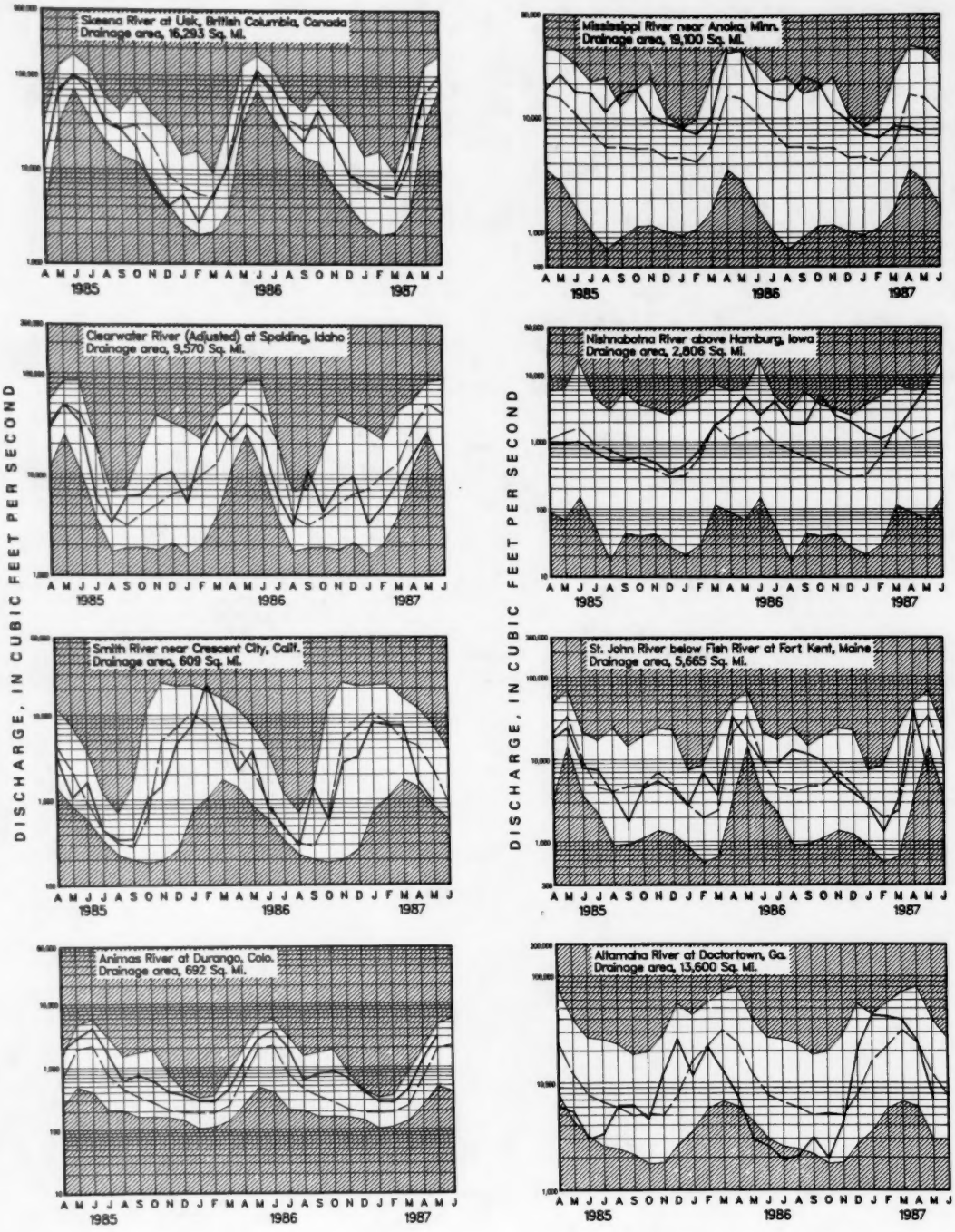


Figure 2. Peak-discharge profile based on indirect peak-discharge measurements and model results. Indirect measurements are believed to be more accurate than dam-break model results.

MONTHLY MEAN DISCHARGE OF SELECTED STREAMS

Unshaded area indicates range between highest and lowest record for the month. Dashed line indicates median of monthly values for reference period, 1951–80. Heavy line indicates mean for current period.


Skeena River at Usk, British Columbia, Canada
Drainage area, 16,293 Sq. Mi.
Mississippi River near Anoka, Minn.
Drainage area, 19,100 Sq. Mi.
Clearwater River (Adjusted) at Spalding, Idaho
Drainage area, 9,570 Sq. Mi.
Nishnabotna River above Hamburg, Iowa
Drainage area, 2,806 Sq. Mi.
Smith River near Crescent City, Calif.
Drainage area, 609 Sq. Mi.
St. John River below Fish River at Fort Kent, Maine
Drainage area, 5,665 Sq. Mi.
Animas River at Durango, Colo.
Drainage area, 692 Sq. Mi.
Altamaha River at Doctortown, Ga.
Drainage area, 13,600 Sq. Mi.
DISCHARGE, IN CUBIC FEET PER SECOND
A M J J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987

TEMPERATURE OUTLOOK FOR JUNE THROUGH AUGUST 1987

PRECIPITATION OUTLOOK FOR JUNE THROUGH AUGUST 1987

NATIONAL WATER CONDITIONS

MAY 1987

Based on reports from the Canadian and U.S. Field offices; completed June 17, 1987

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EXPLANATION OF DATA (Revised April 1987)

Cover map shows generalized pattern of streamflow for the month based on provisional data from 183 index gaging stations—18 in Canada, 163 in the United States, and 2 in the Commonwealth of Puerto Rico. Alaska, Hawaii, and Puerto Rico inset maps show streamflow only at the index gaging stations that are located near the point shown by the arrows. Classifications on map are based on comparison of streamflow for the current month at each index station with the flow for the same month in the 30-year reference period, 1951–80. Shorter reference periods are used for one Canadian index station, two Kansas index stations, one New York index station, and the Puerto Rico index stations because of the limited records available.

The *persistence/change* map shows where streamflow has persisted in the above- or below-normal range from last month to this month and also where streamflow is in the above- or below-normal range this month after being in a different range last month. The table below the map shows areal streamflow range conditions for all index stations reporting data for this month and compares total flow of the stations reporting data for both last month and this month.

The comparative data are obtained by ranking the 30 flows for each month of the reference period in order of decreasing magnitude—the highest flow is given a ranking of 1 and the lowest flow is given a ranking of 30. Quartiles (25-percent points) are computed by averaging the 7th and 8th highest flows (upper quartile), 15th and 16th highest flows (middle quartile and median), and the 23rd and 24th highest flows (lower quartile). The upper and lower quartiles set off the highest 25 percent of flows and lowest 25 percent of flows, respectively, for the reference period. The median (middle quartile) is the middle value by definition. For the reference period, 50 percent of the flows are greater than the median, 50 percent are less than the median, 50 percent are between the upper and lower quartiles (in the normal range) 25 percent are greater than the upper quartile (above normal), and 25 percent are less than the lower quartile (below normal). Flow for the current month is then classified as; *above normal* if it is greater than the upper quartile, *in the normal range* if it is between the upper and lower quartiles, and *below normal* if it is less than the lower quartile. Change in flow from the previous month to the current month is classified as *seasonal* if the change is in the same direction as the change in the median. If the change is in the opposite direction of the change in the median, the change is classified as *contraseasonal* (opposite to the seasonal change). For example: at a particular index station, the January median is greater than the December median; if flow for the current January increased from December (the previous month), the increase is seasonal; if flow for the current January decreased from December, the decrease is contraseasonal.

Flood frequency analyses define the relation of flood peak magnitude to probability of occurrence or recurrence interval. *Probability of occurrence* is the chance that a given flood magnitude will be exceeded in any one year. *Recurrence interval* is the reciprocal of probability of occurrence and is the *average* number of years between occurrences. For example, a flood having a probability of occurrence of 0.01 (1 percent) has a recurrence interval of 100 years. *Recurrence intervals imply no regularity of occurrence;* a 100-year flood might be exceeded in consecutive years or it might not be exceeded in a 100-year period.

Statements about *ground-water levels* refer to conditions near the end of the month. The water level in each key observation well is compared with average level for the end of the month determined from the 30-year reference period, 1951-80, or from the entire past record for that well when only limited records are available. Comparative data for ground-water levels are obtained in the same manner as comparative data for streamflow. *Changes in ground-water levels*, unless described otherwise, are from the end of the previous month to the end of the current month.

Dissolved solids and temperature data for May are given for five stream-sampling sites that are part of the National Stream Quality Accounting Network (NASQAN). *Dissolved solids* are minerals dissolved in water and usually consist predominately of silica and ions of calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride, and nitrate. *Dissloved-solids discharge* represents the total daily amount of dissolved minerals carried by the stream. *Dissolved-solids concentrations* are generally higher during periods of low streamflow, but the highest dissolved-solids *discharges* occur during periods of high streamflow because the total quantities of water, and therefore total load of dissolved minerals, are so much greater than at times of low flow.

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